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Subject: Evaluation of Insects and Diseases in the Wallace Canyon Watershed, Georgetown Ranger District, Eldorado NF (FPM Report No. C95-5)

To: District Ranger, Georgetown RD, Eldorado NF

On August 1, 1995, John Pronos (plant pathologist) and John Wenz (entomologist) from the Forest Pest Management (FPM) Shared Service Area office in Sonora, visited the Wallace Canyon area with Forest personnel. Present from the Eldorado were Dave Bakke, SO; and Tim Dabney, Bob Carroll, and Norman Krizl from the Georgetown Ranger District. The purpose of the visit was to assess the effects of insects and pathogens and discuss options to manage the stand relative to the pests present.

This evaluation focused on a 200-acre stand in the Wallace Canyon Watershed (T.13 N., R. 13 E.). The stand was about 85 years old, at 5200 feet elevation, and contained primarily white fir with some overstory ponderosa pine. There were very minor amounts of incense-cedar and sugar pine. Because of no rail or road access, this area was not logged until the 1960's. Records indicate a subsequent overstory removal of mainly pine in the late 70's and two salvage entries in the 1980's. Site quality is good and basal areas commonly exceed 230 sq. ft./acre. The entire watershed will be managed under the principles of ecosystem management with timber production being one objective for this particular stand.

OBSERVATIONS

Major Pests

Portions of the stand had experienced considerable tree mortality and contained large amounts of down woody material, resulting largely from trees failing at the roots. Mortality and windthrow were almost exclusively in the white fir component and affected all sizes of trees. The fir engraver, *Scolytus ventralis*, (Coleoptera: Scolytidae) and the roundheaded fir borer, *Tetropium abietis* (Coleoptera: Cerambycidae) were present in the lower bole of standing dead white fir (descriptions of pest biologies are included at the end of this report). Fir engraver adult and larval galleries were found throughout the length of the bole on several of the down white fir; galleries of other *Scolyus* sp. were also present in the upper bole and larger branches. Scattered top and branch kill were evident in the stand and likely associated with *Scolytus* spp. activity.

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Many roots of down trees showed laminated decay typical of annosus root disease (caused by Heterobasidion annosum). Several fresh conks of this fungus were found in one windthrown white fir. District personnel familiar with the stand estimated that about 25% of the area showed this pattern of mortality/windthrow. Considering the low frequency of logging in the area, this seems to be a high level of root disease infection. The form of H. annosum present (S-type) will affect true fir and Douglas fir but not pine, incense-cedar or hardwoods. (Attached to this report is Forest Service Handbook 3409.11, R5 Supplement No. 3409.11-94-1 which discusses all aspects of annosus root disease.)

In summary, the major pests active in this stand are specific to, and taking a heavy toll on, the white fir component. Annosus root disease will remain viable on the site for decades, while the fir engraver and wood borers will be a potential threat for as long as stand conditions (mainly root disease and overstocking) remain favorable to it.

Minor Pests

One 8-inch DBH sugar pine was found with old, inactive white pine blister rust (caused by Cronartium ribicola) branch cankers. Sugar pine is rare in these stands, but the presence of rust should not be overlooked if sugar pine is ever considered for planting. Use of rust resistant stock is necessary if this is done.

Several incense-cedar saplings were infected with incense-cedar rust (Gymnosporangium libocedri). This rust fungus is rarely a management concern as it does not cause tree mortality. It may cause distortion of the grain if it becomes established in the bole. The small witches' brooms it forms can be mistaken for true mistletoe infections.

DISCUSSION/MANAGEMENT

It is not intended that one option be selected from the following list and applied to the entire stand or area. Rather, combinations of options may be appropriate at different specific locations within the management area, depending on site conditions and the pests present.

1. **No action.** Allowing the stand to develop without intervention would most likely result in continued mortality and windthrow due to insects and pathogens. Root disease centers would enlarge as long as there is root to root contact between trees (tree size and spacing will determine this). Any true fir regeneration, natural or planted, would be susceptible to infection. Fir engravers would continue to cause mortality and top-kill to fir weakened by a combination of root disease, overstocking, and, at times, inadequate moisture.

Through time, insect and pathogen interactions will lead to continued mortality, top-kill, dieback, windthrow and reduced growth which can result in: (1) lower product merchantability, (2) increased numbers of snags and down woody material, (3) reduced stocking levels, (4) irregular tree distribution because of openings, and (5) increased fuel loadings. Whether these changes are positive or negative, acceptable or unacceptable, depend upon the management objectives for the stand/watershed.

2. **Regulate stocking to improve forest health.** Reducing basal area of overstocked aggregations can increase residual tree vigor and reduce one of the factors predisposing trees, both pine and fir, to bark and engraver beetle attack. This action will not reduce the effects of root disease but may actually increase it. Refer to the discussion of Sporax, below.

3. **Sanitize areas affected with root disease.** Most of the fir within root disease centers are either already infected or will be in the future. A challenge with this root pathogen on true fir is that infected trees do not always show obvious above ground symptoms. This means that identifying root diseased trees and the boundaries of disease centers may be difficult. If true fir growth rates or mortality are unacceptable, consider removing all host trees within disease centers and convert to non-host species, such as ponderosa and rust resistant sugar pine which presently are at low levels in the stand. Heterobasidion annosum will remain active on the site and may continue to expand underground to adjacent fir.

A more aggressive approach would be to sanitize the root disease centers and remove an additional strip of green trees from the adjacent healthy stand. The intent here is to cut uninfected trees far enough in advance of annosus root disease to allow non-parasitic root inhabiting fungi to invade and colonize root systems. Essentially, this would deny H. annosum access to these roots, and the enlargement of centers would be stopped. Based on the size and spacing of trees in this area, the buffer zone would have to be 80-100 feet wide. Treating all cut stumps with Sporax is necessary for the treatment to be effective.

4. **Sporax.** Treatment of stumps with Sporax has been mentioned in some of the preceding management options. This pesticide is effective in keeping annosus root disease from infecting freshly cut stumps, and therefore prevents the start of new disease centers. Sporax does not control H. annosum that is already established in roots. Use of this preventive pesticide is routine in many pine type situations, especially on the east side. Use of Sporax in true fir is less frequent, primarily because of the difficulty in identifying diseased areas and because the annosus is already established in so many true fir stands. Still, Sporax will prevent the start of new disease centers, and its use in the Wallace Canyon Watershed should be considered wherever white fir will remain as a stand component. The easiest approach would be to treat all fir stumps, greater than 12 inches diameter, cut during harvest. It may be questionable to use Sporax within root disease centers where annosus is well established. If it is desirable to reduce the amount of pesticide used or lower cost, Sporax treatment could be limited to areas free of root disease.

5. **Minimize damage to residual trees.** The following guidelines were developed by the Pacific Northwest Station and the R5 Silvicultural Development Unit and apply to second growth true fir stands. These guidelines are intended to reduce logging injury and thereby reduce future losses from decay, including annosus root disease. They include:

A. Restrict time of logging. Do not allow entry during the spring and early summer when tree bark is loose and the likelihood of mechanical damage is greatest.

B. Restrict the size and type of logging equipment. Match the logging system to the topography and use the smallest size of equipment to get the job done.

C. Mark leave trees rather than cut trees.

D. Lay out skid roads in advance of logging. Skid trails should not be cleared wider than the skidding vehicle. Use straight-line skid trails.

E. Leave buffer (bump) trees. When possible, leave cull logs and bump trees along the edges of skid trails. Remove bump trees during the last turn.

F. Limit log length. Relate log length to the spacing of the residual stand.

G. Log skid trails first. Cut the stumps in skid trails as low as possible, preferably 3-4 inches high.

H. Use directional falling. Fall trees toward or away from the skid trails to reduce skidder maneuvering.

I. Limb, top, and buck trees prior to skidding.

J. Do not thin stands of thin-barked trees too heavily. Sunscald can cause considerable damage.

K. Work closely with contractor. Instruct operators in methods of reducing damage. Inform contractor that damage will not be tolerated. Communicate clearly the desired results to the contractor - close supervision may be necessary, especially with inexperienced operators.

John Pronos
JOHN PRONOS
Plant Pathologist

JL Wenz
JOHN WENZ
Entomologist

Enclosures

APPENDIX I - BIOLOGIES OF PEST ORGANISMS

Fir Engraver

The fir engraver (*Scolytus ventralis*) attacks both white and red fir in California. Trees ranging in size from large saplings to overmature sawtimber are susceptible. Attacks can cause patch-killing of cambium along the bole, top-kill, or tree death. Top-kill or death occur most often in firs that have been weakened by root disease, dwarf mistletoe, overstocking, soil compaction, sunscald, logging injury, or drought. The fir engraver also breeds in slash and windthrown trees.

The fir engraver usually completes its life cycle in one year, sometimes two. Adults fly and bore into trees or green fir slash from June to September; larvae, pupae, and adults over-winter under the bark. Pitch tubes are not formed as they are with pine bark beetles; the usual evidence of attack is boring dust in bark crevices along the trunk and pitch streamers on the mid and upper bole. Trees colonized early in the summer may begin to fade by early fall, but those colonized later in the year usually do not fade until the following spring or summer, often after the beetles have emerged.

Annosus Root Disease In True Fir

Heterobasidion annosum (formerly *Fomes annosus*) is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone and a few brush species (*Arctostaphylos* spp. and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is somewhat higher in older, larger fir stands and in stands with high basal areas (over about 330 square feet/acre).

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, *H. annosum* grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness. Losses in true fir from *H. annosum* are mainly the result of windthrow because of root decay, and reduced root systems that

predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

There are two pathogenic strains of the fungus that differ in their ability to infect various conifers in California. The "P" or pine type infects and kills all pines (although susceptibility of pine species vary), in addition to incense-cedar and western juniper. The "S" or fir type infects true fir, Douglas fir and giant sequoia. Knowing which type is active in a stand is important, and will allow favoring alternate conifer species because the two strains do not cross infect between the groups listed above.

White Pine Blister Rust

Blister rust (*Cronartium ribicola*) is caused by an obligate parasite that attacks sugar and western white pines and several species of *Ribes*. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes*. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves re-infect other *Ribes* throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes*, its spread from *Ribes* back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers (these are called **lethal** cankers). Bole cankers result in girdling and death of the tree above the canker. Cankers whose closest margins are more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result (these are called **non-lethal** cankers).

Environmental conditions are critical for successful infection and limit the disease in most years. Moisture and low temperatures favor infection of both hosts, and must coincide with spore dispersal for infection to occur. In California, these conditions occur only infrequently, usually in cool moist sites such as stream bottoms or around meadows. In so called "wave years" when favorable conditions occur, high levels of infection can result. Wave years in California have occurred at approximately ten-year intervals in the past. As one moves from sites most favorable for rust to less favorable sites, the frequency of wave years decreases.

FOREST SERVICE HANDBOOK
San Francisco, CA

FSH 3409.11 - FOREST PEST MANAGEMENT HANDBOOK

R5 Supplement No. 3409.11-94-1

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Document Name	Superseded (Number of Pages)	New (Number of Pages)
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Digest:

62.2 - Adds Regional direction related to annosus root disease.

RONALD E. STEWART
Regional Forester

CHAPTER 60 - MANAGEMENT OF SPECIFIC PESTS

62 - DISEASES.

62.2 - Other Diseases.

1. Introduction to Annosus Root Disease. This section describes annosus root disease in the Pacific Southwest Region, and discusses the biology and resource management implications of the disease. It also presents guidelines and techniques for its detection, and management strategies available for reducing its impact.

Annosus root disease is one of the most important conifer diseases in the Region. Current estimates are that the disease infests about 2 million acres of commercial forest land in California, resulting in an annual volume loss of 19 million cubic feet. Potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of production on the site, and, in recreation areas, depletion of vegetative cover and increased probability of tree failure and hazard. In recreation areas, annosus-infected trees are often extremely hazardous, causing death or injury to visitors, and damage to permanent installations and property.

The goal of annosus root disease management in the Region is to reduce resource losses to levels which are economically, aesthetically, and environmentally acceptable when measured against the objectives of the resource manager. It is possible to reduce the impact of annosus root disease through detection, evaluation, prevention, and suppression. These activities must progress in a planned, timely sequence for successful reduction of annosus root disease impacts. Detection and evaluation in individual stands are normally necessary before undertaking prevention and suppression action. In developed recreation sites, early recognition and removal of hazardous annosus-infected trees is critical, and will greatly improve chances of preventing future damage with minimal site deterioration. Prevention is the most desirable means of reducing losses. Undertake suppression activities only when needed to supplement prevention measures. The basic guidelines for detection (FSM 3410), evaluation (FSM 3420), prevention (FSM 3406.1) and suppression (3406.2) for any insect or disease also pertain to annosus root disease. However, consider the additional specific guidelines for annosus root disease summarized in this section.

Annosus root disease occurs on a wide range of woody plants. The disease affects all western conifers; hardwoods are generally resistant or immune. All the National Forests in Region 5 have reported finding it. Incidence is particularly high on Jeffrey pine in southern California recreation sites and on Jeffrey and ponderosa pine in eastside pine type forests. The disease, endemic in the Red and White Fir forest types, is associated with one-fifth or more of the true fir mortality in the forests surveyed in northern California.

2. Biology.

a. Heterobasidion annosum (Fomes annosus) causes annosus root disease. The fungus is similar to the common heartrot fungi, and forms fruiting bodies or conks in decayed stumps, under the bark of dead trees, or, rarely, under the duff at the root collar.

Infection centers start when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds on the butt. Fresh basal wounds on species other than true fir are rarely colonized. The fungus grows down the stump into the roots and then spreads through root contacts into the root systems of adjacent live trees, resulting in the formation of enlarging disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but is more frequently confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss, or failure at the roots. References that discuss the biology and disease cycle of H. annosum include Otrosina and Cobb 1989, and Smith 1993.

Heterobasidion annosum in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of H. annosum have distinct differences in host specificity. To date, all isolates of H. annosum from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, Pinyon, and manzanita are of the 'P' group. Isolates from true fir and giant sequoia are of the 'S' group. The biological species infecting other hosts are unknown at this time.

This host specificity is not apparent in isolates occupying stumps, with both the 'S' and 'P' groups recovered from pine stumps, and the 'S' group and occasionally the 'P' group from true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers of a species that is susceptible to the particular intersterility group established near these stumps often die shortly after their roots contact infected roots in the soil.

Invasion of freshly cut stump surfaces by germinating spores is a critical stage in the disease cycle. Conks produce spores which disseminate throughout the year, but H. annosum is dependent on favorable environmental conditions for successful germination and establishment. Spores are inactivated by ambient temperatures of 113° F (45°C) and mycelium in wood is killed after exposure for one hour at 104° F (40°C).

Temperatures just below the stump surface commonly reach or exceed the thermal inactivation level (40^{o} C) of mycelium from April to September in the Southeastern United States. In eastside pine on the Lassen National Forest, lethal temperatures reach above 40^{o}C in the top 6 inches of 6-inch diameter stumps when exposed to direct sunlight for several days in the average summer. Temperatures do not approach the lethal range in larger size classes of stumps.

Stumps are susceptible to infection immediately after cutting. Ponderosa pine, Douglas-fir, and coast redwood stumps remain susceptible to infection for 2 to 4 weeks. The decrease in susceptibility with time is probably a result of colonization of the stumps by microorganisms that compete with and replace _H. annosum._ Surface area infection of freshly cut ponderosa pine stumps increases with increased photochemical oxidant injury.

Vertical penetration depends on temperature and extent of injury from other sources. After germination, vertical penetration into pine stumps averages 3 inches/month from October through May and 5 to 6 inches/month from June to October. The rate of vertical penetration in stumps from pine trees severely injured by photochemical oxidants is greater than in those from slightly injured or uninjured trees.

Heterobasidion annosum is an important agent predisposing conifers to bark beetle attack. In pines, the fungus weakens trees and increases their susceptibility to pine bark beetles. Infected true firs are predisposed to attack by the fir engraver. White fir mortality from the annosus root disease-fir engraver complex frequently occurs after tree growth decreases because trees are stressed. As a result of the stress, it is suspected that roots grow very slowly and decay faster than the tree can replace them. This predisposes the tree to fir engraver attack, and causes its death.

3. _Detection._ The general distribution of annosus root disease in the Pacific Southwest Region is known, but information on its location in specific stands may be needed. Based on Region-wide surveys, it is prudent to assume that the pathogen is present in all true fir stands, unless a detailed survey suggests that it is not. Collect location information for stands when planning management activities. Because trees affected by annosus root disease are easily windthrown or fall without visible symptoms that might warn forest recreation managers of impeding failure, the number, size, and locations of annosus infection centers within developed sites or sites planned for development should be determined. Field surveillance and detection surveys will locate occurrences of _H. annosum._

4. _Field Surveillance._ Forest workers and managers, in connection with their regular duties, carry out day-to-day field surveillance (FSM 3411). Stand examinations, inventories and other activities afford excellent opportunities for forest workers to note and record the presence of _H. annosum._

A systematic search for diagnostic symptoms of infection and signs of the pathogen, determines the presence of H annosum. Use the following similar symptoms for correct diagnosis:

a. Pattern of Dying Within the Stand. Root pathogens tend to kill trees over a period of years, with oldest deaths at the center, usually around stumps, and recently dead and dying trees at the margin. In contrast, a characteristic of mortality by bark beetles alone is groups of trees dying at about the same time.

b. Pattern of Dying of Individual Trees. Trees with root disease die gradually, with symptoms progressing from the bottom of the crown upwards, and from the inside of the crown out. Infection of the roots causes: (1) reduced height growth, with crowns becoming rounded; (2) thin and chlorotic crowns, resulting from poor needle retention; and (3) subsequent insect attack of the stressed trees.

c. Symptoms and Signs in Roots and Root Crowns. Use symptoms and signs in roots and root crowns to determine the specific identity of the pathogen. The best evidence of H. annosum is the presence of characteristic fruiting bodies or conks. The annual to perennial, leathery conks vary in size and shape from small button-shaped or "popcorn" conks on the root surface of recently killed seedlings or saplings, to large bracket-type conks. The large conks generally have a light brown to gray upper surface, and a creamy white lower surface with regularly spaced, small pores. Small "popcorn" conks appear as small buff-colored pustules that range in size from a pinhead to a dime. They often have no pore layer. In pines, the conks are found between the bark and wood on stumps, beneath the duff layer at the root crown, and within old stumps. In true fir, the conks are found in cavities hollowed out by the fungus. Conks may be abundant in some stands and scarce or absent in others. Even when present, they can be easily overlooked because of their inconspicuous color and obscure location. Refer to Hadfield, et al. 1986 and Smith 1993 for color photographs of conks.

On pines, additional symptoms may be found by exposing the roots and root crown and examining the inner bark. Choose recently killed or dying trees for examination. Indications of H. annosum infection are: (1) easy separation of the bark from the wood; (2) the separated surfaces are a light brown to buff color, the surface of the wood streaked with darker brown lines; and (3) numerous small silver to white flecks on the surface of the inner bark. Resin often heavily infiltrates infected roots.

Incipient or early stages of wood decay are not very diagnostic. Discoloration may or may not be present and the heartwood remains firm and hard. As the decay progresses, the wood becomes white to straw yellow, separates along annual rings, and may contain elongated white pockets.

If field personnel are unable to identify H. annosum with certainty, or desire confirmation of a tentative identification, the Forest Pest Management Group can assist. Gather specimens of infected root tissue in various stages of decay and any fruiting bodies and send them to FPM pathologists in the Service Areas, or to pathologists in the Regional Office. The specimens must be of tissues in early stages of decay to enable isolation of the pathogen. A completed Forest Pest Detection Report (Form R5-3400-1) shall accompany the samples.

5. Detection Surveys. Personnel may conduct detection surveys (FSM 3412) in areas where no other surveys are scheduled and it is essential that the presence or absence of annosus root disease be known for management purposes. The objective of a detection survey is simply to determine the presence and location of H. annosum.

Because annosus root disease is not always obvious and can be difficult to detect, contact the Forest Pest Management Group with a request to conduct the survey if H. annosum has the potential to adversely affect activities or interfere with resource objectives.

6. Evaluation. The purpose of a biological evaluation (FSM 3421) is to provide information for the resource manager on annosus root disease infestations, their affects on the stand, the management alternatives appropriate in the context of the particular resource management objectives, and the future affects of each alternative. The Forest Pest Management Group or field personnel shall conduct biological evaluations of annosus root disease. Submit requests for a biological evaluation by sending a Forest Pest Detection Report (Form R5-3400-1) or written request to the Regional Forester or FPM Program Leader, or to one of the Service Areas. Field units shall coordinate requests through the appropriate line officer.

7. Management Strategies. Use the integrated pest management (IPM) approach to manage annosus root disease and other pests. IPM involves regulating the pest, the host, and the environment to minimize pest impacts on resource management objectives in ecologically and economically sound ways. Also, use the IPM approach to implement and coordinate activities needed to prevent or suppress pest-related problems. This approach also emphasizes the selection, integration, and use of a variety of tactics on the basis of anticipated economic and ecological consequences. Accomplish control of annosus root disease by prevention of new disease centers, thereby decreasing the risk of stump and wound infection, and through silvicultural manipulation of infested stands to minimize the impact of the disease.

8. Prevention. Prevention (FSM 3406.1) includes activities designed to minimize the impact of a pest before it appears. The objective of annosus root disease prevention is to prevent establishment of the disease in stands. Once annosus root disease becomes established in most forest stands, no economically feasible procedure for directly suppressing the disease is available. Therefore, prevention is the most efficient and economical method of reducing the impact of H. annosum. Prevention of annosus root disease includes treatment of freshly-cut conifer stumps with registered products. Other preventive treatments include carrying out silvicultural activities to lessen stand

susceptibility to the disease, and minimizing logging damage and mechanical injuries.

9. Stump Treatment. Personnel can reduce the probability of infection of freshly cut conifer stumps by the use of a surface stump treatment with registered products. Contact Forest Pest Management for currently registered and effective materials. Treatment of freshly cut conifer stumps with two borate products (sodium tetraborate decahydrate and sodium octaborate tetrahydrate) indicate at least 90% efficacy in preventing infection. The borate in the formulations is toxic to the spores of the fungus and prevents germination; it does not have an effect on existing infections. Apply the products according to label directions. For maximum effectiveness, it is imperative to apply the material as soon after felling as practical and that the application cover the entire stump surface and other areas where the bark has been knocked off. The requirement for application in timber sales and other non-force account work shall be part of the contract or cooperative agreement. A Regional C provision is available for inclusion in timber sale contracts.

R-5 FSM 2303 requires treatment of all conifer stumps in recreation sites. The same direction shall apply to other high value areas, such as progeny test sites, seed orchards, and areas of high value trees, such as giant sequoia groves. In eastside pine or mixed conifer type stands, where surveys have indicated high levels of annosus root disease, treatment of conifer stumps 12 inches or greater in diameter is highly recommended during chainsaw felling. When mechanical shearers are used, the minimum diameter should be reduced to 8 inches. These areas include the eastside pine and eastside mixed conifer types on the Modoc, Lassen, Plumas, Tahoe, Sequoia and Inyo National Forests; the Goosenest Ranger District, Klamath National Forest; and the McCloud Ranger District, Shasta-Trinity National Forests.

In all other areas, consider stump treatments on an individual stand basis. The line officer is responsible for the decision to treat freshly cut conifer stumps, and shall base that decision on information available for the specific situation in the particular stand in question. This information should include:

a. The objectives and management direction for the stand.

b. The level of annosus root disease currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of H. annosum and indications of infection in living trees.

c. An estimate of the cost-effectiveness of the treatment.

d. A Forest Pest Management biological evaluation or an on-site visit.

10. Avoiding Cambial Damage. In addition to being an aggressive colonizer of freshly-cut stumps, H. annosum can also act as a wound parasite by attacking living trees through injuries that expose cambial tissue. The fungus, as well as other decay fungi, are likely to colonize logging injuries, especially those in contact with the ground. Trees

with nonresinous wood, such as true fir and hemlock, are more likely to be infected following injury and to have more extensive decay than species with resinous wood, such as Douglas-fir and the pines. Decay caused by H. annosum is common behind fire scars and other basal wounds in true fir. It may be possible to minimize losses by preventing fires that expose cambium when underburning for fuels reduction, and by reducing mechanical injuries during stand entries.

Other methods of prevention have been suggested, but consider these methods experimental until there is demonstrated efficacy under California conditions. These experimental methods include: (1) thinning during the hotter summer months; (2) creation of high stumps, and, (3) control of stocking density in true fir stands.

11. Suppression. Suppression (FSM 3406.2) of annosus root disease includes the reduction of damage to acceptable or tolerable levels. Direct suppression procedures for H. annosum, such as stump removal, creation of buffer strips, and soil fumigation, are costly and considered experimental. Indirect suppression options, that is, those that alter conditions favoring the pest through the application of silvicultural methods of stand manipulation, are available. These methods include species conversion, thinning in true fir stands, and in recreation areas, thinning and interplanting with hardwoods.

a. Species Conversion. Because of host specificity of the 'S' and 'P' types of H. annosum, favor the non-infected host species (see item 2.a.). In mixed conifer stands with infected true firs, the stand my be converted to pines and incense-cedar with little risk of subsequent infection. If pines are infected, favor true fir. In recreation areas, favor existing hardwoods or the non-infected conifer species. Since hardwoods are resistant, the fungus will eventually die out over a period of 2 to 4 decades, depending on stump size. Then, take steps to regenerate the conifers.

b. Thinning in True Fir Stands. Field observations suggest that removal of slow growing fir and thinning of overstocked stands to increase tree vigor may reduce the impact of the disease, given that the residual trees are capable of responding to release.

c. Revegetate Disease Centers. If consistent with site-specific objectives, resistant species can be used to revegetate active annosus centers. Leaving the centers barren or revegetating with hardwoods will allow the fungus to eventually die out over a period of several decades or more. Favoring hardwoods already present and planting suitable hardwoods provides a barrier of nonsusceptible roots that may limit the spread of infection centers. Thin dense pole-sized stands of susceptible conifers and interplant with hardwoods. Doing this minimizes opportunities for root contact and reduces the risk of further spread. It also increases tree vigor, which reduces risk of bark beetle attack.

d. Stump Removal. Removal of stumps and roots infected with *H. annosum* would reduce the amount of inoculum of the fungus on the site, and allow for earlier successful revegetation of the site with susceptible conifers. Stump removal as a suppressive method is being tested in several recreation sites, and its efficacy has not yet been demonstrated.

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